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Department of Mines and Geology

Mysore State

NOTES

ON

THE OCCURRENCE OF LEAD, ZINC AND ANTIMONY ORES IN MYSORE

BY

A. M. SEN, M.Sc., F.G.S.
Assistant Geologist

BANGALORE:
PRINTED AT THE GOVERNMENT PRESS
1917

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PREFACE.

In their Order No. G. 11337—Geol. 20-15-10, dated 19th February 1917, the Government of Mysore desired me to collect and print separately in the form of a booklet all the information available on the subject of the occurrence of lead, zinc and antimony deposits in Mysore. All this information, which is at present scanty, has already found a place in the Departmental Bulletin No. 7 and the Records Vol. XV, Part I, and to publish the same matter separately would be little better than a mere repetition.

So, with a view to present the subject in the form of a booklet meeting the requirements of the Government and the students and general public of Mysore interested in the mineral development of their country as well, some more useful and readable matter has been carefully collected and added under my instructions and direction; the attempt, it is hoped, will merit their appreciation. Since the scope of the booklet is very limited no attempt has been made to enter into the detailed processes of metal extraction etc., and as the ores of lead and zinc are found in nature in almost the same way and invariably associated with one another, their geological distribution and genesis have been treated together under one heading.

B. JAYA RAM,
Director (in charge),
Department of Mines and Geology.

24th April 1917.

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NOTES ON THE OCCURRENCE OF LEAD, ZINC AND ANTIMONY ORES IN MYSORE.

LEAD.

It is doubtful if lead has ever been found in the metallic state as a true natural product, since the small quantities found associated with the ores of lead may have been accidentally reduced.

Lead Ores.

Lead ores occur usually in three different ways:—(1) By themselves; (2) associated with zinc; and (3) associated with silver.

Pure lead ore series consists essentially of the following compounds: Galena (Sulphide of lead), Cerussite (white lead ore or carbonate of lead), Anglesite (Sulphate of lead) and Pyromorphite (a Chloro-phosphate of lead).

Galena.

The most abundant of the lead compounds is galena (PbS). It occurs in massive form, both cleavable and granular-coarse and fine, and also as crystallised individuals, exhibiting cubic and octahedral forms. The crystalline form appears usually in fissures, the other forms are found both in beds and fissures. Pure galena has a bright metallic lustre, especially on cleavage faces, and dark grey colour. The cleavage is perfect parallel to the cubic faces and less perfect parallel to those of the octahedron. It is opaque and has great weight, the specific gravity being 7·4 to 7·6; while its hardness ranges between 2·5 and 2·75. Pure galena is composed of 86·6% of lead and 13·4% of sulphur. The percentage of lead in

the ore as commonly dressed is about 80. It melts at red heat and volatilises at bright red heat in the presence of air. Mostly it is a primary ore mineral probably replacing sphalerite to some extent. It is used for direct reduction to lead. The smelters sometimes use it as a flux for rebellious argentiferous and auriferous ores. For such a purpose it occasionally sells at a slight premium.

The minerals usually associated with galena may be divided into two main types—(*a*) metallic and (*b*) non-metallic. The chief minerals of the metallic type are blende (sphalerite-sulphide of zinc), pyrites, marcasite, chalcopyrites, and also variable amounts of silver, antimony, bismuth and cadmium and sometimes tetrahedrite and nickeliferous pyrites. Galena almost invariably contains silver, which partly replaces the lead in its combination with sulphur, without altering in any way the crystalline form and general appearance of the ore. A galena containing 2 parts of silver in a thousand would be spoken of as an argentiferous galena, for the reason that even this small amount of silver can be extracted with profit from the lead after it is smelted from the ore. Galena which is non-argentiferous is usually known as soft lead. Antimony, if present, exercises a serious influence upon the quality of the lead extracted from the ore.

The minerals of the non-metallic type associated with the metallic forms are calcite, dolomite, fluorite, quartz and barytes. Each of the minerals associated with the ores when occurring in quantity may serve as the gangue or matrix of the ores. Some of these, especially fluorspar and barytes have been worked out profitably in some mines.

Cerussite.

This is carbonate of lead ($PbCO_3$) and is also known as "white lead ore" or "Wool mineral." It often occurs in veins of galena and is a secondary mineral, produced by the chemical alteration of galena by oxidising agents. Pure cerussite contains 77·5% of lead, corresponding to 83·5% of lead oxide, which is combined, with 16·5% of CO_2. When pure, it is white and crystalline, forming transparent rhombic crystals isomorphous with arragonite. It

usually occurs in places as a dingy white coating over crystals and masses of granular galena; it is also found in granular forms, and as stringers and small irregular masses.

The cerussite, though sometimes observed as incrusting the galena, has been found occasionally in crystals on the galena. Some specimens of galena, not incrusted by cerussite have dull surfaces which are much roughened, pitted from etching. When broken, the same specimens exhibit a bright metallic lustre of the unaltered galena inside. The alterations are found either partial or complete and nearly all gradations may be observed between these two extremes. Not infrequently, crystals of white and light grey colour are found in clusters and aggregates, mixed with earthy impurities. This ore is very seldom smelted apart from galena for the extraction of the metal.

Anglesite.

This is sulphate of lead ($PbSO_4$) and occurs in the form of rhombic crystal as a secondary mineral, derived from galena and is very rarely found in any quantity. When pure it contains 68·3% of metallic lead. It is also found massive, and sometimes in stalactitic nodular forms often with a core of galena with concentric structure. It is very brittle with a conchoidal fracture. Its hardness is 2·75 to 3 and specific gravity 6·12—6·39. In some places it has a highly adamantine lustre, which is resinous and vitreous in other specimens. The colour is generally white but sometimes tainted yellow, grey, green or blue.

Pyromorphite.

It is a chloro-phosphate of lead—$Pb_5Cl(PO_4)_3$—found in the upper portions of many lead lodes, and is formed by the action of phosphoric acid solutions on pre-existing lead compounds. It contains 75·8% of lead. It crystallises in the hexagonal system and is often found in rounded barrel-shaped forms. It is brittle, with a hardness of 3·5–4 and specific gravity of 6·5–7·1 when pure. It has a resinous lustre, uneven fracture, and colour of various

shades of green, yellow and brown; sometimes it is greyish white to milk-white.

In some mines the lead ores are admixed in large and small proportions with those of zinc. In the fresh rock the sulphide form of lead, galena, is usually mixed up with the sulphide form of zinc, sphalerite. When these original metallic sulphides are altered by oxidation, they give rise to the secondary ores, cerussite and calamine (zinc carbonate). Sphalerite (ZnS) and galena (PbS) are changed by oxidation to zinc sulphate ($ZnSO_4$) and lead sulphate ($PbSO_4$). The solutions of these sulphates, reacting on water carrying lime and carbonic acid, give rise to the carbonates of lead and zinc respectively. Galena is usually oxidised with greater difficulty than the sulphides of zinc and iron; and as it is less soluble than the rock in which it occurs, galena is usually found in larger quantities than the secondary ores with which it is mixed up in the weathered zone.

Properties and Uses.

Ordinary lead is blue-grey in colour with a metallic lustre. The economic use of lead depends chiefly upon its physical properties of softness and plasticity. Its hardness is 1·5 and specific gravity 11·37. As lead melts easily at red heat and behaves like a viscous liquid under a pressure of about 33 tons per square inch, it may be made to flow through comparatively small apertures. It is used for lining sinks and cisterns, etc., as it may be rolled easily into sheets. It is also made into pipes either by casting or forcing the molten metal, just before solidifying, by hydraulic pressure, through the annular space of a steel cylinder, from which the solidified metal comes out with the necessary form and dimensions. This process is known as "squirting."

Lead should not be used for cisterns and pipes to carry soft water for human consumption, as, though lead is not acted upon by pure water, acidulated water containing chiefly carbonic acid will readily dissolve a part of the metallic lead and convert the metal into a carbonate, which dissolves in water in small quantities.

Repeated doses of water containing lead carbonate will have apoisonous effect and may produce what is known as "lead poisoning."

Lead cannot be used for being drawn into thin wire owing to its want of tenacity. Lead hardened by the addition of antimony is used by the type-founder. Type metal may be an alloy of lead with $\frac{1}{3}$ to $\frac{1}{4}$ of its weight of antimony; but the alloy commonly used contains 70 parts of lead, 18 of antimony, 10 of tin and 2 of copper. Some alloys of type metal may also contain zinc.

Lead is used for making bullets and small shot; but to make the bullets harder, lead is alloyed usually with antimony and sometimes with tin. Small shot for fowling pieces are composed of lead containing from 3 to 6 parts of arsenic in a thousand, which has the effect not only of hardening the lead slightly but also of enabling it to take a nearly spherical form, when the melted metal is dropped through a colander into water.

Vessels for various chemical manufactures are mostly made of lead as it resists the action of sulphuric, hydrochloric and hydrofluoric acids in a far greater degree than iron, copper, zinc or tin. Nitric acid, if strong, scarcely attacks lead, though this acid when diluted readily dissolves it.

Lead alloys with various metals, such as copper, tin, bismuth, zinc, antimony, mercury, potassium, sodium, platinum, chromium and manganese.

The alloy of lead and tin, known as pewter, consists of 4 parts of tin and 1 part of lead; it is harder, more tenacious and has a lower melting point than either of the component metals. If the quantity of lead does not exceed the above proportion, the alloy may be used for drinking vessels without any danger of lead poisoning.

It is stated that an alloy made up of equal weights of lead and copper makes a good bearing metal which is suited specially for high temperature work and for machinery exposed to acids. Alloys for die-casting with lead, zinc and tin as bases have low melting points; they are easily cast but are weak. Antimony lessens shrinkage and increases hardness. Alloys with 17·3 per cent antimony have the greatest hardness. Lead alloys with bismuth in all

proportions; but the malleability of the alloy is diminished if more than equal weight of bismuth is added.

Common solder used for tin plate is an alloy of equal weights of lead and tin; the fine solder contains 2 parts of tin and 1 of lead, while the coarse solder 2 parts of lead and 1 of tin.

Bell metal is an alloy of 4·3 per cent lead, 80 per cent copper, 10·1 per cent tin and 5·6 per cent zinc.

Litharge or lead monoxide (PbO) is used in the manufacture of flint glass, as a glaze for earthenware and for the preparation of lead acetate, lead nitrate, lead plaster and for drying oil.

Red lead, whose chemical composition may be represented by the formula Pb_3O_4, is commercially used as a pigment and also in the manufacture of flint glass, as a cement in making steam-joints and in the manufacture of secondary batteries.

White lead, which is the most important of all the basic lead carbonates, with the chemical composition of $2PbCO_3 . Pb(HO)_2$, is manufactured on a large scale by several processes for use as a pigment.

In England the price of lead was as low as £12-10s. per ton in pre-war days. Just before the war it was from £18 to £19-5s. per ton. In 1916 it rose as high as £36; and in March 1917, the price came down to £29-10s. to £30-10s. per ton.

Extraction.

Lead is easily reduced from its ores by two different methods.

In the first method (known as the reduction process) the lead sulphide (galena) is partially roasted in a reverberatory furnace where it is converted into oxide and sulphate of lead. The temperature is then raised, when the oxide and sulphate react on a further amount of the sulphide forming metallic lead and evolving sulphur dioxide.

In the second method (called the precipitation process) the sulphide is reduced by metallic iron. This depends on the fact that at a high temperature metallic iron, in contact with lead sulphide, is converted into ferrous sulphide, with separation of lead. The ores, either in the raw state or after previous calcination, are

smelted in a blast furnace with coke and either metallic iron or such materials as will yield iron under the furnace conditions.

The lead first obtained by either of these processes usually contains antimony, tin, copper and other metals. These impurities are removed by heating the metal in a shallow flat-bottomed reverberatory furnace. Most of these metals oxidise before the lead and form a dross on the surface. This is known as the "softening" of lead. The silver is however not removed by this operation. This metal is extracted by a desilverising process.

Lead in Mysore.

"A small quantity of argentiferous galena (lead sulphide) was discovered by Mr. Sambasiva Iyer about a mile south-east of the village of Kurubarmardikere in the Chitaldrug Taluk. The ore occurs in small stringers from $\frac{3}{4}$ to $1\frac{1}{2}$ inches thick in gritty calc-chlorite schists which are probably alterations of the gray trap. There are only a few short stringers and some pits failed to reveal any tendency to increase in size or number. The clean ore assayed 134·65 ozs. of silver and 72·29 per cent of lead, but the quantity is very limited and the expense of extraction would be too high to permit of profitable working.

In a few places a little galena has been noticed in quartz reefs, for instance: just west of the ghat section on the road to Hiriyur close to Chitaldrug town; on the east slope of Nisanigudda, near Nakikere, Hiriyur Taluk; and to the north-west of Arothekoppal in the Tirumakudlu-Narsipur Taluk. It is also found sometimes in the gold quartz of the Kolar Field and in other places where gold mining has been tried, but in none of these cases has any noteworthy body of ore been disclosed."*

A prospecting license has been taken out for the galena deposits near Kurubarmardikere in the Chitaldrug Taluk, and only 400 lbs. of ore have so far been excavated up to 31st March, 1917.

Lead has also been found in very small quantity in some old workings at Bukkambudi in the Tarikere Taluk. Mr. B. N.

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* Bulletin No. 7—Department of Mines and Geology—The Mineral Resources of Mysore—page 119.

Venkataramaiya brought samples from these old workings and two of them X/497 and X/499 were assayed for gold and silver with the following results:—

	X/497	X/499
Gold	Trace ...	Trace
Silver	1 oz. 10·75 dwts. per ton.	20 oz. 6·75 dwts. per ton.

These two samples were crushed and washed and the metallic contents were concentrated. One concentrate obtained from these two samples and forming 0·52 per cent of the total weight of the material treated, gave the following results on analysis:—

Insoluble residue	8·94	per cent
Lead	52·25	,,
Silver	0·05	,,
Zinc	0·77	,,
Antimony	0·10	,,

Zinc, antimony and silver are present in negligible quantities, while lead forming 52·25 per cent of the concentrate, constitutes only 0·27 per cent of the sample. A further reference to the Bukkambudi old workings will be made later on while considering the zinc deposits.

ZINC.

Zinc is stated to have been found in Australia in the uncombined state; apart from this, metallic zinc is not met with in nature, though its combinations with other substances occur in large quantities in many other localities.

Zinc Ores.

As already stated before, the ores of zinc and lead are usually associated with one another, together with the various minerals of the metallic and non-metallic types, the chief amongst which are galena, pyrite, chalcopyrite, quartz and calcite. The galena ores in which tetrahedrite (a complex sulpho-antimonite of copper $4Cu_2S.Sb_2S_3$ probably containing a little arsenic and zinc and known as grey copper crystallising in the cubic system with tetrahedral habit) is in abundance are low or wanting in blende and those containing much blende are usually free or almost free from tetrahedrite. The principal zinc ores are the following:—

(1) Sphalerite (sulphide of zinc); (2) Calamine (carbonate of zinc); (3) Smithsonite (silicate of zinc) and (4) Zincite (or red zinc ore, oxide of zinc).

The nomenclatures of the two zinc ores—carbonate and silicate—have given rise to some confusion. The American mineralogists, such as Dana and others, describe the silicate as calamine, while the carbonate ore as smithsonite; whereas the English mineralogists use the two terms *vice versa*. Here we will follow the latter in the use of the two terms calamine and smithsonite.

Sphalerite.

It is also known as Zinc Blende and is commonly called by the miners "Black Jack" or simply "Jack." It is sulphide of zinc (ZnS), containing 67 per cent of metallic zinc and 33 per cent of sulphur. The prices of the ore are usually made on 60 per cent

basis. Owing to impurities present, the chief amongst which are lead and iron, the percentage of zinc varies from 50 to 65; an ore grading above 62 per cent commonly commands a premium in price.

Blende occurs in various forms of the regular system and often shows slightly rounded faces. It is transparent to translucent and varies in colour from a slight rosin yellow to a deep ruby red, steel blue or a jet black, the black colour being due to impurities, particularly iron. It has a very perfect rhombic dodecahedral cleavage and with a little care all the 12 faces can be cleaved out of a single piece. It may occur in fine cleavable form intergrown with a small amount of galena and small grains of chalcopyrite. It is also found in massive specular form intergrown with other minerals and in semi-crystalline form, or in disseminated grainsand stringers. The hardness varies between 3·5 and 4 and the specific gravity between 3·9 and 4·1. It is sold entirely to manufacturers of spelter.

Calamine.

It is anhydrous zinc carbonate, also known as zinc-spar ($ZnCO_3$). It contains 64·8 % of zinc oxide with 52·03% of metallic zinc, when pure. The clear stalactitic varieties contain from 40 to 50% of zinc and are much preferred by the oxide burners. In some places in Spain, the zinc carbonate is found in combination with the hydrated oxide of zinc, so that the ore contains as much as 57% of zinc. Calamine is usually white if pure, but is commonly of a buff or brown colour, due to the presence of oxide of iron, the latter being objectionable owing to its corrossive effects on the clay vessels used in smelting the ore. The hardness is usually 5 and the specific gravity ranges between 4·30 and 4·45.

Calamine occurs in veins, usually traversing limestones, and is associated with blende, galena and *electric calamine* which resembles calamine in appearance but shows electrical polarity when heated. The electric calamine is a hydrated silicate of zinc. In some mines in America, calamine is found in the residual clays derived from the magnesian limestone, usually concentrated at the bottom of the clays and immediately overlying the weathered surface of the limestone. It is intimately associated with smithsonite. It may also

occur in the granular and earthy form as mammillary and stalactitic incrustations and as a porous or spongy material, the cavities being sometimes filled with a powdery earthy form of the ore, and also as pseudomorphs after blende and other earlier formed minerals.

It is chiefly found as a secondary mineral produced by the oxidation of blende in the presence of hydrated calcium carbonate probably in the following manner:—

$$ZnS + 2O_2 = ZnSO_4.$$

$$ZnSO_4 + CaCO_3 + 2H_2O = ZnCO_3 + CaSO_4.2H_2O.$$

It is sold sometimes chiefly to be burned to oxide of zinc or zinc white which is a valuable base for paints.

Smithsonite.

It is a hydrous silicate of zinc ($H_2Zn_2SiO_5$), containing theoretically 67·5% of zinc oxide with its equivalent of 54·16% of metallic zinc, 7·5% of water and 25% of silica. Silicate as usually marketed carries from 40 to 50% of metallic zinc.

Like calamine it occurs as a secondary mineral derived from the alteration of blende. It is usually associated with calamine, and sometimes it is very difficult to separate the two ores, when they are intimately mixed up together. It also occurs in the residual clays, usually in their lower parts, next to the irregular weathered surface of the underlying limestone. Both mammillary and stalactitic incrustations of the mineral have been observed at times between layers of the more solid massive zinc ore. Smithsonite is found very commonly in granular massive and honey-comb forms. Sometimes it occurs in sheet form in limestone areas.

It is transparent to translucent, has a vitreous lustre and is colourless, clear white and yellowish to brown. The hardness is between 4·5 and 5 and specific gravity between 3·4 and 3·5. It tends to gelatinise with acids and thus it can be distinguished from the zinc carbonates which effervesce. It is commonly associated with clay and the so-called "tallow clays" often contain, as a result, large amounts of zinc. Large quantities of the silicate are used by spelter manufacturers; while it is also used to be burned to oxide of zinc. It is said that a retort mixture of equal parts of calcined

silicate and roasted blende makes a spelter which rolls to very valuable sheet metal.

Red Zinc Ore (*Zincite*).

It is red oxide of zinc (ZnO), usually coloured by the oxides of iron and manganese; it is white in the pure state, and contains 80% of the metal. It sometimes forms red, translucent, prismatic crystals. It occurs associated with franklinite—a mixture of the oxides of zinc, manganese and iron, which may contain 5 to 20% of zinc and is first smelted for that metal and then for manganiferous iron. Hardness is between 4 and 4·5 and specific gravity between 5·43 and 5·7.

Properties and Uses.

When pure, the metallic zinc has a bluish white colour and a specific gravity of 6·86 to 7·3 and hardness 2. Zinc is quite brittle at ordinary temperature; but between 100°C and 150°C it is rendered malleable and can be rolled into thin sheets. For this purpose, it should be free from iron and lead. At above 200°C it becomes brittle again and to a greater extent. It may be obtained in very fine powder by pouring melted zinc into an iron mortar and well stamping it with the pestle at the moment of solidification. Powdered zinc may be used as a metallic paint for iron to prevent it from rusting.

Zinc is used for galvanizing sheet iron to produce what is known as "galvanised iron". The surface of the iron is thoroughly cleansed and then it is immersed in melted zinc which is kept covered with powdered sal-ammoniac (hydrochlorate of ammonia), this salt having the property of dissolving the oxide of zinc from the surface of the bath. The layer of zinc coating the iron prevents it from rusting. Galvanized iron is better able to withstand the action of air and moisture than tinned iron; hence it is extensively used for wire netting, corrugated roofing, water tanks and other purposes where the metal is exposed to the oxidising influence of air and water.

Owing to the malleability of zinc at suitable temperatures, it has been largely used for gutters, rain-pipes, cisterns, baths,

chimney pots and roofing for which it is highly suited for its lightness and by its resistance to the action of air and moisture.

Zinc melts at about 420°C and boils at 1,040°C. When heated in the air, zinc burns with a bluish flame, forming zinc oxide Zinc oxide, commercially known as zinc white, is made from the spelter in Europe but it is made directly from the ore in America. Zinc oxide is used chiefly as a pigment, either alone or mixed with white lead or barytes. Although it is not equal to white lead in covering power, it possesses the advantage that it does not get black by exposure to atmospheric sulphuretted hydrogen. It is also used to a less extent in the manufacture of rubber goods.

Zinc readily combines with tin, antimony and a few other common metals, forming with copper a number of alloys known as "Brass". The brass alloys are known by many different names, with corresponding variable compositions. A little addition of tin or lead enables the brass to break up more easily for engraving or for working at the lathe.

In England the price of spelter before the war was about £18 per ton; it rose as high as £103 per ton in 1916 and in March 1917 the price came down to £54 to £59-15-0 per ton.

Extraction.

Zinc is extracted from its ores by reduction by means of carbon; as this reduction takes place at 1,320°C and as zinc boils and distils freely at 1,090°C, zinc is evolved as vapour from its oxide and is to be condensed in the liquid state. The ores are calcined, so as to obtain the oxide of zinc; they are mixed with carbon and distilled, when the oxygen combining with carbon passes off as carbonic acid gas and the zinc which comes out in vapour is condensed. This is the principle of the various processes which are used in different works.

Flotation methods are now greatly used in Europe and Australia for the concentration of zinc.

Electrostatic machines are used by some companies in America for obtaining zinc concentrates. These are used chiefly for zinc blende-marcasite ores.

Roasting and magnetic separation continue in favour of the separation of pyritic zinc ores.

The latest metallurgical process for zinc production adopted on a commercial scale at several places in America, is the electrolytic method, which has yielded spelter assaying above 99·9% zinc. The electrolytic spelter may be produced directly from many ores with profit. The process depends on a cycle of operations depending upon the presence of manganese, which serves as a carrier of oxygen. The ferrous iron is thus oxidised to ferric iron, enabling the iron to be completely separated; a purified solution would thus be obtained from which zinc may be recovered by electrolysis.

Zinc in Mysore.

"The mineral blende (sulphide of zinc) has been found in the Kolar mines and in some old workings such as those at Bukkambudi in the Tarikere Taluk but only in comparatively small quantity. At Bukkambudi the talc-chlorite schists in the neighbourhood of the old working have mineralized streaks or bands containing finely divided sulphurets, such as galena, blende and iron pyrites, but the proportion of these is small and the mineralized zones of no great extent. In the old workings a few more highly mineralized bands occur in which the total concentrates would not average more than about one per cent of the rock. The low grade and the complex character of the concentrates preclude any reasonable prospects of working even if the mineralized zones were of large extent and this does not appear to be the case. It has been suggested that richer patches existed and were worked by the ancients for silver, lead and zinc, but it is more than doubtful if they could have treated such a complex mixture which would be a difficult proposition even under modern conditions. The rock is veined with quartz and carries a little gold and it is more probable that the old workings were excavated on some patches or lenses carrying fairly rich free gold."*

Results of analysis of a concentrate from samples obtained from the Bukkambudi old workings have already been stated before (page 8.)

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*Bulletin No. 7 of the Department of Mines and Geology—The Mineral Resources of Mysore—pages 119-120.

GEOLOGICAL DISTRIBUTION AND GENESIS OF LEAD AND ZINC ORES.

The ores of lead and zinc occur in the identical way and they are usually associated with one another and also with the same gangue minerals, the lead ores sometimes replacing the zinc ores and *vice versa*. The veins of lead and zinc are usually connected with acid intrusive rocks of all ages; but not infrequently the ores exhibit a remarkable preference for certain kinds of rocks. The fissure veins in intrusive rocks are usually narrow and sharply defined, but they develop to a considerable extent in many places. Both lead and zinc ores favour the acid rather than basic rocks, though they have been noticed in both. These lodes are usually associated with granites, gneisses and schists and other igneous and metamorphic rocks; while intrusive quartz porphyry, syenite and other dykes have often given rise to fissures in which lodes of galena and blende have resulted due to the access of mineralising solutions.

Though the most important lead and zinc lodes of the world occur in the Palæozoic rocks and especially in limestones and dolomites of that period, their occurrences in association with such easily alterable rocks are not limited to any particular geological age. The younger or tertiary intrusives, associated with the veins of lead and zinc, often contain appreciable quantities of gold and silver, sometimes in such large quantities that they may be classified as gold and silver veins.

The formation of ore deposits and the concentration of the metalliferous materials have been brought about by a number of different processes, both chemical and physical; and these processes to which the lead and zinc deposits in different areas have been observed by various workers to owe their origin are briefly noted below.

Ores of Pneumatolytic and Hydatogenetic Origin.

The lead and zinc ores occur as fissure or vein deposits which are occasionally of pneumatolytic and generally of hydatogenetic (hydrothermal) origin. Ores of pneumatolytic origin are chiefly derived from plutonic intrusive rocks at the time of intrusion by means of steam and magmatic gases dissolved in them under a high pressure and above their critical temperature.

Hydatogenesis is generally post-pneumatolysis. The ores of hydatogenetic or hydrothermal origin are formed by the intrusive actions of the igneous rocks and they have been deposited from extremely hot solutions, such actions being not pneumatolytic. In some cases, however, it has been noticed that depositions appear to have started with pneumatolysis and finished with hydatogenesis.

Metasomatic Ore Deposits.

The chemical process by which one substance is replaced by another, without necessarily retaining the form or volume of the original mineral through the agency of circulating water, is known as metasomasis. Such waters carrying mineral matters in solution and frequently flowing downwards bring about the mineral replacement and production of ore deposits. These deposits may be roughly divided into two classes—the bedded deposits and the fissure deposits. In the former class the ores are deposited along the strata and the most important of them are the iron and manganese deposits; in the latter class the ores occur in the walls of a fissure or vein, probably cutting obliquely the planes of stratification, and the chief of these are the silver, lead and zinc deposits.

The limestones of the Palæozoic age are generally found rich in lead and zinc ores in many parts of America and Europe. These ores are often the results of metasomatic replacement, galena occurring with pyrites and sphalerite in the replacement veins and beds in limestone and in lavas. The lead deposits in the limestones are metasomatically replaced by lead ores near the lodes and sometimes fill up the cavities and open fissures formed by the solvent action of water.

The ores of lead and zinc which result from metasomatic replacements are most commonly the galena and blende and more rarely cerussite, calamine and smithsonite. Galena and zinc blende appear in almost all cases to be original minerals. But the carbonates and sulphates are often formed in the upper part of the ore body from the sulphides by the action of percolating meteoric waters.

It often happens that zinc deposits are found in larger and richer bodies in the lower part of the veins, while the lead compounds, being less soluble, are deposited in the upper portions of the lode. Zinc, being more soluble, remains in solution and travels downwards towards the lower levels. Zinc sulphide, being a more soluble metallic sulphide, may be easily extracted from a mixed lead and zinc lode and deposited at a lower level by descending waters.

Calamine, like cerussite, occurring as an alteration product of the sulphide, is found as a metasomatic deposit owing to the action of zinc solutions on limestone and replacement of the calcium carbonate by the corresponding zinc salt. Calamine often contains iron and copper pyrites and other metasomatic minerals, such as chalybite. In some localities calamine occurs in veins and pockets, resulting from the alteration of zinc blende in places.

In many places the original ores were the metallic sulphides—blende, galena and pyrites—for the deposits appear to become highly sulphidic in depth, calamine and cerussite appearing as results of oxidation of pre-existing sulphides.

Mr. C. R. Von Hise in his report on the Lead and Zinc Deposits of the Ozark Region (The Mississippi Valley) says: "The lead and zinc ores were widely dispersed through the Silurian limestones. The ores were first segregated in the limestones by an artesian circulation, confined above and below by shales. Later the upper shale was removed by erosion and from this time on, the conditions were changed and the descending meteoric waters produced a second concentration. Thus were formed the ore deposits now mined."

Rocks such as limestone, which may be acted upon by

percolating waters, thus making them deposit their metalliferous contents, would often contain the minerals in veins and fissures traversing them, formed either by joints or by faults. But these may ultimately fail in depth and in consequence the lead and zinc deposits would deteriorate.

The phosphates of lead and zinc are generally of secondary origin; but in places such deposits are metasomatic in character and are produced in highly phosphatic beds traversed by mineralising solutions.

Bedded Ores due to Precipitation.

The process by which some mineral constituents of a solution are deposited in a solid form is known as "precipitation"; it always depends on the liquid being in a state of super-saturation with regard to the substance undergoing precipitation.

The sulphide ores, occurring as bedded deposits, are chiefly derived from true chemical precipitation and are more or less independent of metasomatic processes. They are formed either by the action of sulphuretted hydrogen on metallic solutions or by the reduction of soluble sulphates by organic matter.

The precipitated sulphides of lead and zinc occur either alone or combined in the mineral fahlore (tetrahedrite) which contains copper. A few occurrences of these sulphides have been noticed in the Mesozoic clays in Britain.

Metamorphic Ore Deposits.

These are generally found associated with rocks which have changed their mineralogical character and partly their chemical composition, after their original deposition or formation. These metamorphic changes are usually brought about in a rock mass by the influence of high temperature or pressure of sufficient intensity to generate heat.

The ores associated with metamorphic rocks may occur either as layers and lenticles with many important deposits of oxides and sulphides or as large irregular ore-masses, occurring as metamor-

phosed metasomatic deposits or metasomatic contact deposits and veins, in the country rock of which the characteristic metamorphic minerals may be found. Sulphides of lead and zinc together with those of antimony are some of the ores associated with metamorphic rocks. In some parts of Europe, blende occurs as a contact deposit in a zone of halleflintas lying between the Archæan schists and the younger granitic masses, and the galena deposits are associated with metamorphosed calcareous lenticles in the Archæan schists.

The metamorphic contact deposits are found only within the region of metamorphism surrounding some intrusive igneous rocks; and they are formed locally by metamorphic changes in some pre-existing metasomatic or precipitated metalliferous deposits or they may be due to metasomatic change of the country rock produced with its metamorphism at the same time.

Blende and galena deposits have been noted in some parts of Europe to occur as metamorphic contact deposits.

In some places in America the contact deposits are found to be very important commercially and of great interest geologically. Sometimes they are found to form irregular masses.

Secondary Changes in Ore Deposits.

These generally take place in the upper parts of lodes and in those parts of the bedded ore masses, which are liable to be acted upon by ascending or descending meteoric waters. These changes often bring about secondary enrichment in metalliferous deposits and by this process material from one part of the ore body may be transferred to another. They also cause a considerable change in the composition of the rocks, owing to addition or elimination of some of the ingredients.

Almost all the sulphidic deposits, occurring near the surface are liable to changes of this nature, which resemble the ordinary weathering of rocks near the surface. That cerussite and smithsonite can be derived as secondary products from the sulphides of lead and zinc occurring in limestone has already been mentioned before. From the carbonate or sulphate, the lead may again be

reconverted to sulphide by the action of the sulphides of iron or zinc, thus:—

$$PbCO_3 + FeS_2 + O_2 = PbS + FeCO_3 + SO_2.$$

$$PbSO_4 + ZnS = PbS + ZnSO_4.$$

Such secondary deposits of various lead ores occur in many places in America.

Placer Deposits.

Galena and zinc blende have also been met with in the placers, which are concentrations of these metalliferous deposits brought down by running waters and laid down at various levels, probably in several stages.

ANTIMONY.

Antimony is occasionally found in nature in the metallic state in small quantities in various parts of the world. Metallic antimony crystallises in the rhombohedral system and is found associated with silver and other ores. It has a thin white streak, hardness of 3 to 3·5 and specific gravity of 6·65 to 6·72.

Antimony Ores.

Antimony occurs in many minerals in combination with sulphur or oxygen or as antimoniates of gold, silver and copper. The minerals associated with the antimony ores are of both the metallic and non-metallic types. The metallic associates are chiefly galena, zinc blende, pyrite, chalcopyrite and sometimes gold, silver, bournonite and sulphides of arsenic, mercury and bismuth; while the non-metallic minerals are chiefly quartz, calcite and barytes.

The principal ores of antimony are the following :—

(1) Stibnite (sulphide of antimony).
(2) Valentinite (antimony trioxide).
(3) Jamesonite (sulphide of lead and antimony).
(4) Cervantite (antimony ochre—tetroxide of antimony).

Stibnite.

The ore from which the metal is largely extracted is stibnite (Sb_2S_3)—also known as "Antimony glance," antimonite or grey antimony ore. When pure it contains 71·4 per cent of antimony and 28·6 per cent of sulphur. The mineral crystallises in the orthorhombic system, but it more commonly occurs as a compact bundle of dark grey acicular crystals, often exhibiting a blue iridescence due to a thin film of oxide. Its hardness is about 2, and the specific gravity varies between 4·52 and 4·62; its colour and streak are lead grey. It is often associated with galena, iron pyrites and with quartz and barytes while small quantities of arsenic and zinc are

sometimes present. When exposed to the atmosphere, stibnite is first oxidised to kermesite or red antimony or antimony blende—a mixture of the oxide and the sulphide ($2Sb_2S_3$, Sb_2O_3) and then on further oxidation valentinite (Sb_2O_3) is usually formed and sometimes cervantite (Sb_2O_4). Stibnite melts easily even in the flame of a candle and so it can be readily separated from the gangue. Stibnite, like galena, reacts on solutions of the noble metals and it precipitates gold in bright scales from a solution of gold chloride.

Valentinite.

This mineral (Sb_2O_3) crystallises in the rhombic system and its usual colour is white; sometimes it is reddish grey or brown. It contains 83·3 per cent of antimony and its hardness is $2\frac{1}{2}$ to 3 and the specific gravity 5·56. It is translucent to sub-transparent, with a white streak. It occurs usually in the upper portion of stibnite deposits and in veins traversing metamorphic rocks.

Jamesonite.

It is a lead grey mineral having the composition 2 PbS. Sb_2S_3. When pure it contains 29·5 per cent of antimony, 50·8 per cent of lead and 19·7 per cent of sulphur. Almost all the varieties contain a little iron and occasionally silver, zinc and copper. It crystallises in the orthorhombic system, occurring usually in acicular crystals or in fibrous massive or compact massive forms. It has a metallic lustre and greyish black streak. It is opaque and has a specific gravity 5·5-6·0 and hardness 2 to 3.

Cervantite.

It is also known as antimony ochre. It is generally a secondary mineral, resulting from the alteration of stibnite and other antimonial ores. Its composition is, according to Dana, Sb_2O_4 or Sb_2O_3. Sb_2O_5 and it contains 78·9 per cent of antimony. It crystallises in the orthorhombic system, occurring usually in acicular crystals. Sometimes it is found massive, and also in powder or incrustations. It is generally yellow, though it is nearly white or reddish white in some cases. It has usually a greasy lustre and

yellowish white to white streak. The hardness is 4-5 and specific gravity 4·084.

Properties and Uses.

Metallic antimony is a bright, highly crystalline and very brittle metal with a bluish-white colour and has a coarsely laminated or granular structure according as it has been slowly or quickly cooled. At ordinary temperature it is not acted upon by air or oxygen, but when heated it burns brilliantly being rapidly oxidised to antimony trioxide. The metal melts between 425° and 450° C. * and at a higher temperature it vaporises producing a thick white smoke of oxide of antimony. While solidifying, antimony expands; and so when alloyed with other metals, it expands slightly thus enabling them to take very fine and sharp castings. It is so brittle that it can be readily powdered finely in a mortar, while with the slight tap of a hammer an ingot may be easily broken, the fractured surface exhibiting large shining plates. It is a bad conductor of heat and electricity.

The metal by itself has but few uses. If an acid solution of an antimony salt is treated with zinc, finely powdered metallic antimony is produced, known as "Iron black." Articles made of plaster of Paris or zinc are polished with this powder, to give the appearance of steel.

Antimony very easily forms alloys with most of the heavy metals, tin, lead, zinc, copper, bismuth and iron, increasing their hardness. Melted gold absorbs the vapour of antimony but gives it up almost totally when heated further. Gold loses its malleability when 1/2000 of antimony is present. An alloy of 9 gold and 1 antimony is white and very brittle, with an amorphous porcelain-like fracture.

The more important alloys are (1) Antifriction or "white" metal; (2) Type metal; (3) Hard lead; (4) Britannia metal.

Antifriction or white metal is used for machinery, and its composition depends on the nature of work for which it is intended. It usually contains tin, antimony and copper and sometimes lead.

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* Thorpe and a few others state 630·5°C. to be the melting point of antimony.

Type metal is made of lead, antimony and tin, copper being sometimes present. It fuses readily and expands on solidification.

Hard lead is chiefly used in the manufacture of shrapnel bullets and consists of lead and antimony.

Britannia metal, also known under several other trade names, is chiefly used in the manufacture of domestic table ware, such as spoons, forks, tea-pots etc. It consists chiefly of tin, antimony, copper and occasionally small quantities of zinc, lead and bismuth. This alloy is silver white in appearance, takes better polish than tin and has a higher melting point.

Lead-antimony alloys are used for manufacturing acid-resisting valves. Antimony when added to brass, deepens its colour and the final product gets finer in texture and takes better polish than ordinary brass.

The following table giving an approximate composition of some industrial antimony alloys is obtained from the Bulletin of the Imperial Institute, Vol XIV, No. 3 :

Alloy	Antimony	Tin	Lead	Zinc	Copper	Other metals
	per cent	per cent	per cent	per cent	per cent	per cent
Antifriction, for rapid working	77	17	...	...	6	...
,, extra hard	82	12	...	2	4	...
,, medium	26	72	...	...	2	...
Type metal	27·8	...	50	...	...	Bismuth 22·2
,, ,, ...	23	22	55	...	...	...
Hard lead	22	...	78	...	...	...
Britannia metal	5	94	...	...	1	...
,, ,, ...	10	80	1	...	9	...
Stereotype plate	14·3	...	85·7	...	...	...
Linotype metal	13·5	2	84·5	...	...	...
Pewter	7	88·5	...	1	3·5	...

Antimony compounds are extensively used in the arts, industries and medicine.

Antimoniate of lead known as " Naples yellow " is a fine permanent yellow pigment and is used in oil-painting and in the glass and ceramic industries.

Antimony pentasulphide--with a fine orange yellow colour—is used in the rubber manufacture as a pigment and carrier of sulphur. Antimony compounds are also used in dyeing and in medicine.

Smelting of Antimony Ores.

Antimony sulphide is usually concentrated by the process of "liquation" to get rid of certain impurities before smelting. Owing to the lower melting point of stibnite, it is heated in a perforated clay pot in a furnace. The melted metal is allowed to drop into a second pot or run into a cavity at the back of the furnace, from which it is taken in ladles for moulds. The liquated material is made into bricks weighing about 15 lbs. each and is sold as "crude antimony" or "needle antimony."

Ores containing both oxide and sulphide of antimony cannot be liquated, as they form a pasty mass when melted, due to the formation of "antimony glass." The residues after liquation, containing some unmelted sulphide, are smelted for antimony regulus.

In England the metallic antimony or the "regulus of antimony" is extracted from its sulphidic ores, by melting the high grade or liquated ores in crucibles with metallic iron as a desulphurising agent in a reverberatory furnace with condensing chambers. As the mass melts, iron removes the sulphur forming a slag of iron sulphide and an impure metallic antimony is left behind which is afterwards refined. After refining, the metal is run into moulds for "star" metal. When the antimony gets its whole surface covered with large fern-like crystals, it is termed "star antimony." The production of the star is usually accepted in commerce as an indication of purity.

When mixed and low grade ores are to be treated for the extraction of the metal, sublimation process is used by which the volatile trioxide (Sb_2O_3) is produced. The crude sulphide is at first liquated. The liquated sulphide is then mixed with about half its weight of charcoal, to prevent the mass from caking and then carefully roasted. The sulphide is partially converted to Sb_2O_3, which passes into the flues and is there condensed, leaving a mixture of Sb_2O_4 and unchanged sulphide. The residue, containing the

tetroxide and sulphide, is mixed with an additional amount of charcoal and with carbonate of soda and heated to redness in a crucible. The result of the reduction is that metallic antimony is produced which is afterwards carefully refined and starred.

Valuation of Antimony Ores.

The pre-war price of antimony ore in England varied from £6-10-0 to £10 per ton for 50 per cent ore. The price rose very considerably in 1915 and 1916 to 10*s.* to 10*s.* 6*d.* per unit for 50 per cent ore, *i.e.*, as much as £25 to £26-5-0 per ton and even as high as £40 per ton.

The price of antimony regulus in pre-war days varied from £27 to £30 per ton; in 1915 it rose as high as £125 and it has come down to £85 per ton in March 1917, when the antimony ore was quoted at 9 to 10*s.* per unit for 50 per cent ore.

Messrs. Cookson & Co., Ltd., the well-known antimony manufacturers, have supplied the following particulars to the Bulletin of the Imperial Institute, Vol. XIV, No. 3, 1916, with regard to the present basis of purchase of antimony ores required for the manufacture of the metal for munition purposes.

The price of stibnite ores containing 60 per cent or more of metallic antimony is 11*s.* per unit; it is 10*s.* 9*d.* per unit when the antimony content is between 55 and 60 per cent, and 10*s.* 6*d.* per unit when between 50 and 55 per cent. These are gross prices which are liable to a discount of 2½ per cent, and the metallic contents are calculated on the net dry weight received at buyer's works deducting 12 lbs. per ton draft.

The objectionable impurities are lead, bismuth, arsenic, copper and zinc, and these are penalised as follows:—Lead up to 0·3 per cent is not taken into account and for each 0·1 per cent or part in excess of this an amount of 5*s.* per ton is deducted. The maximum lead content allowed is 1·5 per cent, copper and arsenic are allowed up to 0·1 per cent; but for each 0·1 per cent up to 0·5 per cent a deduction of 7*s.* 6*d.* per ton is made. Zinc and bismuth are highly objectionable impurities and are allowed only in traces.

The oxide ores with antimony below 50 per cent would pro-

bably be saleable; but their price would be 1*s*. less for each unit below 50 down to 45 than the price of 10*s*. 6*d*. per unit for 50 per cent stibnite, and 2*s*. less per unit below 45 per cent.

Geological Distribution and Genesis of Antimony Ores.

The ores of antimony are very frequently found as abnormal developments of lodes containing chiefly other metals; but in some places they occur as principal minerals in veins and are usually deposited as the sulphide or pure metal from alkaline solutions, together with some oxides which may be occasionally found. The antimony ores are usually of limited extension in strike; they do not generally go down to a considerable depth and sometimes they rapidly pinch out. Now-a-days the lodes worked out have a width of few decimetres only, and seldom exceeding one metre.

The antimony ores occur principally in quartz veins in or near igneous intrusive rocks of all ages, which may intersect Palæozoic or Mesozoic strata, the ore being associated with various minerals as already stated. The ores sometimes associated with gold are found in Europe in veins of various dyke rocks, such as kersantite, lamprophyres, porphyries, traversing granites, gneisses and schists. Sometimes in quartz dyke stibnite occurs in stringers or pockets associated with mercury ore. In some places the distribution of the ore in veins is irregular, antimony ochre occurring at the top of the veins and stibnite below. Some of the veins are mere strings of quartz, while in places they attain a thickness of several feet. Such vein deposits are usually of hydatogenetic and some probably of pneumatolytic origin.

Some deposits of antimony ores—especially the oxides, are now regarded by many as metasomatic in origin. These ores sometimes occur in irregular layers running parallel to the associated beds of limestone of the Palæozoic age. Such metasomatic deposits are usually distinguished by the absence of gangue. Other antimony ores, chiefly stibnite, occurring in seams, pockets and masses in association with limestones, appear to be intimately connected with and dependent on intrusions of igneous masses; and they may be either of hydatogenetic or metasomatic origin. Often

in quartz veins and fissure veins intersecting Palæozoic and Meso zoic limestones, ores of stibnite occur, sometimes as tufts of stringers or in pockets.

Like other metallic sulphides, stibnite may occur as a precipitated deposit, impregnating some sedimentary rock, in which it is finely disseminated as crystals or grains or as more or less continuous bands and as bedded masses. Sulphide of antimony has similarly been noted to occur associated with metamorphic rocks.

As already noted, stibnite is often altered due to secondary changes caused by weathering and meteoric waters to oxides of antimony, valentinite and cervantite (antimony ochre).

The antimony ores—especially the sulphides—may also occur as placer deposits, associated with gold placers as in Russia in Asia.

Antimony in Mysore.

" The existence of small quantities of antimony ore, in the Chitaldrug District, has been known for many years and in 1888 some samples of stibnite are said to have been collected by Mr. Mervyn Smith and sent to the Mysore Exhibition. In 1889 Mr. Sambasiva Iyer during the course of survey found some specimens of antimony ochre (cervantite) in the same locality but only in small quantities. More than one prospecting license has been taken out since and a large number of pits sunk in the search for both gold and antimony but without any satisfactory results. Loose blocks of a quartzose rock containing stibnite and cervantite were found, but neither the amount nor the grade of the ore was sufficient to justify further work."*

The antimony ore in Mysore occurs about a mile south-east of the village of Chikkannanhalli in the Chitaldrug Taluk and about 9 miles north of the town of Chitaldrug. As already stated, antimony is greatly in demand now for munition purposes, and the price has gone up very high, nearly three or four times the normal rate. Owing to these favourable conditions, Mr. J. Burr, of Bangalore, took out a prospecting license in December 1915. This

* Bulletin No. 7, Department of Mines and Geology—Mineral Resources of Mysore, page 120.

license, on the sanction of Government, has been transferred to the Axen Antimony Mines Company of Bombay, of which Messrs. Monro, Green & Co., are the managing agents. A fresh application for renewal of the license is under the consideration of Government. A considerable amount of excavation has been made and up to 31st March 1917, 134 tons 15 cwts. of ore have been collected. In the first quarterly report of 1917, the managing agents of the Company state that the total quantity of the ore in stock consists of stibnite and cervantite of varying composition, as shown in the following table:—

Ore	Quantity		Sb_2O_4 %	Sb_2S_3 %	SiO_2 %	Fe_2O_3 %	CaO %	As	Au, Ag & Pt.	S %
	Tons	Cwts.								
(1) Stibnite ...	1	5	...	73·36	18·22	2·02	2·02	Trace	Nil	19·03
(2) Cervantite ...	28	10	40·36	...	...	...	...	...	...	...
(3) Cervantite ...	45	...	23·60	...	...	...	...	...	...	...
(4) Cervantite ...	60	...	16·80	...	70·22	6·62	4·82	...	...	0·43

Near the block a refining furnace has been built and the construction of a reverberatory furnace with a 400 feet long condensation chamber has been practically completed, the object being to reduce the low grade ore and place "starred" metal on the market. The total quantity of antimony regulus extracted from various samples of ore up to 31st March 1917 is 45 lbs.

Dr. W. F. Smeeth, Director of the Department of Mines and Geology, paid a visit to the block from the 21st to 24th March 1916 for the purpose of inspecting the works and sampling the ores. He says thus on pages 46—48, Part I., Vol. XV., Records of the Department of Mines and Geology:—

"The ore occurs in an area close to the nulla running east and west about half a mile south of △ 2,582 and pieces of float can be picked up, over a distance of 200 yards or so, in the rubble in the nulla and on the banks—especially the north bank. From the pits which have been sunk to a depth of 20 feet it is found that the

ore occurs in a narrow quartz vein in chloritic trap. The vein or veins are narrow, from a few inches to a foot or two in width, and dip towards the east and south-east at gentle inclinations of from 10° to 30°. The quartz carries a little ore some of which is stibnite (Sb_2S_3) and most of which is cervantite (Sb_2O_4) or antimony ochre. Most of the mineral excavated from these veins is too poor to be worth treatment, but a few tons might be picked out which would be of distinctly lower grade than Grade II mentioned below.

In the nulla itself some large blocks were found which probably once formed an upper portion of the vein and which contained a good deal more of the sulphide and oxide than the vein material excavated from the pits. Probably they represent a portion of the vein containing fairly large segregations of the sulphide, part of which has been converted subsequently to oxide. The ore stacks which have been collected consist almost entirely of these loose boulders which have been broken up and roughly dressed and of smaller pieces of float ore which have been picked up.

I found that the stacks were of very mixed composition and quite unsuitable for sampling; so I had them pulled down and sorted the whole into two grades:—

Grade I.—containing most of the sulphide with some oxide and

Grade II.—consisting mainly of oxide with some sulphide which could not be easily separated.

Grade I.—formed a stack 6′-4″ × 7′ × 1′-2″ giving 51·7 cubic feet of ore and weighing approximately 3 tons.

An average sample of the stack was taken and yielded the following analysis:—

Silica	... ...	31·38 per cent.
Total Antimony	... ...	45·84 „
Total Sulphur	... ...	6·61 „
Calculated Sb_2S_3 =	... ...	23·12 „
Calculated Sb_2O_4 =	... ...	36·80 „
Gold	... ...	trace.
Silver	... ...	0·35 oz. per ton.

Grade II.—formed a stack 9′ × 9′ × 2′-10″ giving approximately 229·5 cubic feet weighing $11\frac{3}{4}$ tons.

An average sample was taken and gave the following analysis :—

Silica	...	... ...	52·33 per cent
Total Antimony	...	... ...	28·29 ,,
Total Sulphur	...	... ...	0·73 ,,
Calculated	Sb_2S_3 =	... ...	2·55 ,,
	Sb_2O_4 =	... ...	33·56 ,,
Gold	...	... ...	trace.
Silver	...	... ...	0·4 oz per ton.

From the analysis it is obvious that the ores as a whole are not of high grade and that Grade I contains a large admixture of oxide which could be dressed out only with considerable difficulty. Taking the two stacks we may reckon that we have about 1·37 tons of metallic antimony in grade II. It is difficult to say how much could be recovered by smelting. The loss in antimony is usually large and the loss on the low grade stuff would doubtless be very considerable. At present there is no more ore comparable to Grade I in sight, but a few more tons comparable to Grade II might be sorted from the dumps.

I am informed that 1 ton of sulphide ore and 1 ton 6 cwts. of oxide ore have been sent to Bombay for experimental treatment and some information as to the results of smelting may be expected shortly.

I doubt if the antimony which may be obtained will pay for the money spent on it, even at present prices. It may however serve to recoup some of the expenditure and help towards further prospecting, but unless something better is met with, the proposition has little chance of paying its way.

The ore contains a little iron, but appears to be practically free from lead, zinc, tin and arsenic."

In the report of Messrs Monro, Green & Co., dated the 4th August 1916, it is stated that the faulted lode in the main working was productive of about 20 tons of ore—the stibnite carrying 73·36 per cent of Sb_2S_3, with a coating of cervantite containing about 48

per cent of Sb_2O_4, the remainder of the lode though poor was found to yield 6·80 to 16·80 per cent of antimony oxide.

The quantity obtained from the lode inspected by Dr. Smeeth did not run to more than about 2 tons.

No report has yet been obtained as to the results of experimental smelting at Bombay. Two small ingots of "starred" antimony, and one five pound ingot of "starred" regulus, exhibiting beautiful stars, obtained from ores smelted near the Chikkannanhalli Mines, have been kindly presented to the Museum of this Department by Messrs. Monro, Green & Co.

"The following Table shows the analyses of dressed samples of the ore :—

Analyses of Antimony Ores.

Number	1	2	3	4	5	6
SiO_2	41·81	42·30	...	53·62	41·60	
Sb_2S_3	...	53·10	...	...	1·57	
Sb_2O_4	...	...	...	43·60	48·06	
Sb (total)	38·86	(37·70)	48·00	(34·40)	(37·00)	40·00
S	13·61	...	...	0·60	...	
Fe_2O_3 and Al_2O_3	2·56	1·00	...	1·92	2·45	
SnO_2	...	nil.	...	...	3·60	
PbO	trace	nil.	...	trace	0·44	
As	nil.	nil.	...	nil.	nil.	
Zn	...	nil.	...	...	nil.	
CaO, MgO, etc....	...	3·60	...	...	2·28	

In these analyses of the dressed ore, which have been kindly furnished by the licensee, Nos. 1, 2 and 3 are sulphide ores and Nos. 4, 5 and 6 are oxide ores. Nos. 3 and 6 have evidently been dressed rather more carefully, but on an average the sulphide ore is not likely to exceed 38 per cent antimony and the oxide ore 35 per cent antimony in dressed bulk samples. If some of the dressed ore can be sold so as to cover expenses, it will be worth while doing some further work on the chance of striking some

richer material; but it is evident that even at the high prices now ruling, the proposition is hardly likely to pay unless a marked improvement takes place. If we take the high quotation of Rs. 8 per unit at Bombay for 38 per cent ore, the ore would be worth Rs. 304 per ton and this has to cover the cost of bagging and transport amounting to about Rs. 34 and leaving Rs. 270 to cover cost of mining, dressing and sundries. If, as is reported, it takes 100 tons of rock to yield one ton ore we have only Rs. 2-12-0 per ton to cover these charges and it is rather questionable if there would be any balance for profit. If then the question of making a profit is a doubtful one when the ore fetches Rs. 300 or so at Bombay, the proposition would certainly be not attractive in normal times when the ore would fetch only Rs. 100 or less and this accounts for the fact that it has been left alone for so many years. The grade of the ore body would have to improve considerably before work under normal conditions could be seriously entertained.

The high prices now ruling make it possible to collect the float ore and to do certain amount of excavation, sorting and dressing and to recover most or all of the expenditure with the chance that the work so done may disclose some more valuable ore bodies."*

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* Bulletin No. 7—Department of Mines and Geology—Mineral Resources of Mysore—pages 121—122.

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